

Description

ION BEAM APPARATUS, AND ION BEAM PROCESSING METHOD,
AND HOLDER MEMBER

Technical Field

The present invention relates to an ion beam apparatus, an ion beam processing method and a holder member for processing a cross section for observation in a sample that is used to observe a micro-structure of a semiconductor and the like, for example.

Background Art

Traditionally, for example, an ion beam apparatus is widely used for the purpose of preparing a TEM sample that is used to observe defects generated in wafer fabrication processes of semiconductor memory and the like by a TEM (Transmission Electron Microscope) and the like. In this type of ion beam apparatus, ion beam fabrication by the focused ion beam (FIB: Focused Ion Beam) allows processing a micro-cross section for observation in a particular portion of a TEM sample, and allows preparing the TEM sample for a relatively short time.

However, when the traditional ion beam apparatus is used to perform ion beam fabrication for forming a micro-cross section in a sample, gallium used for an ion source of the focused ion

beam is injected into the cross section of the sample to alter the sample amorphously, and gallium forms a damage layer which is a so-called fracture layer with the damaged cross section. Since the sample having this fracture layer formed on the observation cross section adversely affects relatively high-powered TEM observation by the fracture layer, there is a disadvantage that a normal crystal lattice image cannot be obtained, causing a problem in highly accurate observation up to the atomic level of the cross section. Therefore, the fracture layer needs to be removed so that the fracture layer of about 30 nm formed on the cross section of the sample is reduced up to about 10 nm.

Then, it is considered that the acceleration energy of the focused ion beam is reduced to decrease the thickness of the fracture layer, or that after fabrication by the focused ion beam, an ion beam of relatively low energy is irradiated onto the cross section to remove the fracture layer formed on the cross section. Furthermore, the ion beam for removing the fracture layer is irradiated onto the cross section to form a new fracture layer on the cross section as well. However, a fracture layer formed by using an argon ion beam, for example, is about a few nm, and thus it does not cause problems in observing the cross section.

Accordingly, for the traditional ion beam apparatus, an apparatus is proposed which has a removing beam part that

irradiates an argon ion beam onto the cross section of a sample formed by irradiating a focused ion beam and removes a fracture layer on the cross section.

This traditional ion beam apparatus has a holder part which holds a sample, a processing beam part which processes a cross section in the sample, the removing beam part which removes the fracture layer on the cross section processed in the sample, and an observing beam part which observes the cross section of the sample. The holder part has a holder member which holds the sample on the tip end side thereof. The processing beam part is disposed vertically above as facing the top surface side of the sample held by the holder member. The removing beam part and the observing beam part are disposed at the positions to sandwich and face the cross section of the sample.

In the traditional ion beam apparatus thus configured, the processing beam part irradiates the focused ion beam from a gallium ion source onto the sample held by the holder member to process the cross section, and the removing beam part irradiates the argon ion beam onto the cross section of the sample to remove the fracture layer of the cross section (ion milling). Then, the observing beam part irradiates an electron beam onto the cross section of the sample where the fracture layer has been removed, and an observed image of the cross section of the sample is obtained.

In the meantime, in the traditional ion beam apparatus described above, as shown in Fig. 11, in irradiating an argon ion beam onto a cross section 104 of a sample 103, the argon ion beam is widely irradiated onto the area other than the cross section 104 of the sample 103. Therefore, the argon ion beam is irradiated onto a step part and the like adjacent to the base end side of the cross section 104 of the sample 103, and is partially irradiated onto the top surface and the like of the step part to fly secondary particles of the fracture layer, causing a problem that the secondary particles of the removed fracture layer are again attached onto the cross section 104 and contaminate it.

Then, an object of the invention is to provide an ion beam apparatus, an ion beam processing method, and the holder member, which can excellently remove the fracture layer from the processed surface of the sample.

Disclosure of the Invention

In order to achieve the object, an ion beam apparatus according to the invention has: a holder member which holds a sample; and a removing beam source which irradiates a gaseous ion beam onto a processed surface of a sample held by the holder member and removes a fracture layer on the processed surface, the processed surface being formed by irradiating a focused ion beam. And, the gaseous ion beam is irradiated from a holding

end side of the sample with respect to a direction vertical to the processed surface so that its irradiating direction is tilted with respect to the vertical direction.

According to the ion beam apparatus of the invention thus configured, when the gaseous ion beam is irradiated onto the sample and the fracture layer is removed, the gaseous ion beam is irradiated onto a step part formed adjacent to the processed surface, and thus secondary particles are flown. However, the flown secondary particles do not travel in the direction where they do not reach the processed surface. Therefore, it is reduced that the fracture layer removed by the gaseous ion beam is again attached onto the processed surface.

Furthermore, the holder member provided to the ion beam apparatus according to the invention preferably has a base part which is rotatably supported about a first axis in parallel with a horizontal direction, and a holding part which is rotatably disposed about a second axis orthogonal to the first axis at a tip end side of the base part and holds the sample. The holder member is rotatably disposed about the first axis, and thus the arrangement of the removing beam source with respect to the holder member and the flexibility in the irradiating direction of the gaseous ion beam can be secured. Moreover, the holder member has the holding part which is rotatably disposed about the second axis, and thus the irradiating directions of the focused ion beam and the gaseous ion beam

can be varied with respect to the sample held by the holding part.

Besides, an ion beam processing method according to the invention has a first step of irradiating a focused ion beam onto a sample and forming a processed surface; and a second step of irradiating a gaseous ion beam onto the processed surface of the sample and removing a fracture layer on the processed surface. And, at the second step, the gaseous ion beam is irradiated from a holding end side of the sample with respect to a direction vertical to the processed surface of the sample so that its irradiating direction is tilted with respect to the vertical direction.

In the ion beam processing method according to the invention thus configured, at the second step, the gaseous ion beam is irradiated from the holding end side of the sample with respect to the direction vertical to the processed surface of the sample so that its irradiating direction is tilted with respect to the vertical direction. Therefore, the gaseous ion beam is irradiated onto the step part formed adjacent to the processed surface, and thus secondary particles of the fracture layer are flown. However, the flown secondary particles travel in the direction where they do not reach the processed surface. Accordingly, it is reduced that the secondary particles of the fracture layer removed by the gaseous ion beam are again attached onto the processed surface.

In addition, the holder member according to the invention has: a base part which is rotatably supported about a first axis in parallel with the horizontal direction; and a holding part which is rotatably disposed about a second axis orthogonal to the first axis at a tip end side of the base part and holds a sample where a focused ion beam is irradiated to form a processed surface.

According to the holder member of the invention thus configured, when an ion beam is irradiated onto the sample to form the processed surface, the holding part is rotated about the second axis with respect to the irradiating direction of the ion beam. Thus, the irradiating direction of the ion beam can be varied with respect to the processed surface of the sample. Accordingly, the irradiating direction of the ion beam is varied with respect to the processed surface and processing by the ion beam is repeated for several times. Then, streaks generated in the processed surface are gradually reduced in the sample held by the holding part when fine bumps and dips and the border between different materials exist on the top surface of the sample, removing the streaks. Furthermore, the streaks described above are also removed from the sample even when processing by the ion beam is done as the irradiating direction of the ion beam is varied with respect to the processed surface.

Moreover, for the gas described above, for example, oxygen, argon, helium, neon, xenon, krypton, radon and the like are

named as they do not greatly affect the characteristics of the sample.

Besides, the fracture layer in the invention is, for example, the layer that is altered amorphously by injecting gallium into the processed surface and damaged by gallium when the focused ion beam of gallium is irradiated onto the processed surface of the sample.

In addition, the holding end side of the sample described above is the end side of the sample held by the holder member which is contacted with the holder member. For example, it is the end side of the sample facing the holding surface of the holder member on which a support is contacted when a small piece of the sample is held by the holder member through the support such as a dice.

Brief Description of the Drawings

Fig. 1 is a cross section schematically illustrating an ion beam apparatus according to the invention;

Fig. 2 is a cross section of A-A schematically illustrating the ion beam apparatus shown in Fig. 1;

Fig. 3 is perspective diagrams; (a) is a perspective diagram illustrating a sample in which a cross section is processed, and (b) is a perspective diagram illustrating the sample in which the cross section has been processed;

Fig. 4 is a perspective side view schematically

illustrating a holding part of a holder member;

Fig. 5 is a schematic diagram illustrating the holding part and a slide plate;

Fig. 6 is a perspective side view schematically illustrating an example of another drive mechanism which drives the holding part;

Fig. 7(a) is a schematic diagram illustrating a state that the cross section is processed in the sample, Fig. 7(b) is a schematic diagram illustrating a state that an inert ion beam is irradiated onto the cross section of the sample, and Fig. 7(c) is a schematic diagram illustrating a state that an electron beam is irradiated onto the cross section of the sample;

Fig. 8(a) is a schematic diagram illustrating a sample in which a cross section is formed by a focused ion beam, and Fig. 8(b) is a schematic diagram illustrating the sample in which streaks are formed on the cross section by the focused ion beam;

Fig. 9 is a schematic diagram illustrating a processing state that a cross section is rotated in the irradiating direction of an inert ion beam that is irradiated onto a cross section of a sample;

Fig. 10 is a schematic diagram for describing a state that an the inert ion beam is irradiated onto a cross section of a sample;

Fig. 11 is a cross section schematically illustrating

an example of another ion beam apparatus; and

Fig. 12 is cross sections schematically illustrating states that an inert ion beam is irradiated onto the cross section of the sample in the traditional ion beam apparatus.

Best Mode for Carrying out the Invention

Hereinafter, specific embodiments according to the invention will be described with reference to the drawings.

As shown in Figs. 1 and 2, an ion beam apparatus 1 of this embodiment is a so-called side entry ion beam apparatus, having a vacuum container 10 which processes a sample 3 therein, a holder part 11 which holds the sample 3, a processing beam part 12 which irradiates a focused ion beam from a gallium ion source onto the sample 3 and processes an observation cross section, a removing beam part 13 which irradiates an inert ion beam onto the cross section processed in the sample 3 and removes a fracture layer on the cross section, and an observing beam part 14 which irradiates an electron beam onto the cross section of the sample 3 and observes the cross section.

First, the sample 3 to be processed by the ion beam apparatus 1 is cut out of a wafer in a given flat plate, and then the both ends thereof cut in the width direction to form it in a block shape as shown in Fig. 3(a) beforehand. Then, the sample 3 in a block shape is formed to have the width W_1 of about 0.1 to 0.5 mm. As shown in Fig. 3(b), an observation

cross section 4 is processed on the both ends thereof in the width direction by the ion beam apparatus 1 of the embodiment, and the width W_2 on the tip end side is formed in about a few tens μm , for example.

Furthermore, in the sample 3, a processed surface is formed only on one side in the width direction when the reflection mode for detecting secondary electrons reflected in the cross section 4 is used. Moreover, for the sample 3 in which the cross section 4 is observed by the ion beam apparatus 1 of the embodiment, it is acceptable to apply a sample that a small piece with a processed cross section is cut out by pickup or by liftout and is joined on a dice, other than the sample that is cut out in a block shape by dicing to form the cross section as described above.

The vacuum container 10 has a vacuum chamber 15 which processes and observes the sample 3, the container is disposed and fixed on a mounting base 16. The vacuum chamber 15 is communicated with an exhaust apparatus (not shown in the drawing) through an exhaust pipe 17.

The holder part 11 is disposed on the side surface part of the vacuum container 10, having a holder member 21 in a rod shape which rotatably holds the sample 3 in the directions of arrows a_1 , a_2 in Fig. 1 and the directions of b_1 , b_2 .

As shown in Figs. 4 and 5, the holder member 21 has a base part 22 which its longitudinal side is disposed in parallel

with the horizontal direction, a holder support mechanism 23 which rotatably supports the base end side of the base part 22 in the directions of a_1 , a_2 , a holding part 24 which is rotatably disposed on the tip end side of the base part 22 in the directions of b_1 , b_2 and holds the sample, and a slide plate 25 which rotates the holding part 24 with respect to the base part 22.

The base part 22 is supported by the holder support mechanism 23 rotatably at an angle of about 145 degrees in the direction of a_1 and at an angle of about 35 degrees in the direction of a_2 , for example.

The holding part 24 is formed in an approximately semicircular flat plate, having a mounting recess 27 on which the sample 3 is placed and fixed. The holding part 24 is rotatably supported on the base part 22 in the directions of b_1 , b_2 through a rotational shaft 28 rotatably at an angle of about ± 30 degrees, for example. Moreover, to the mounting recess 27, the holding end side of the placed sample 3 is joined and fixed with a deposition film or solder material, for example.

The slide plate 25 is slidably disposed in the directions of arrows c_1 , c_2 in Fig. 4 along the longitudinal direction of the base part 22. The tip end side of the slide plate 25 is slidably contacted with the arc-shaped outer part of the holding part 24, and the base end side thereof is drawn out of the vacuum container 10. Then, the slide plate 25 is manually operated in the directions of c_1 , c_2 , for example, and thus rotates the

holding part 24 in the directions of b_1 , b_2 in accordance with the sliding amount.

Furthermore, as shown in Fig. 6, for example, it is acceptable that the holding part 24 is configured to be rotated by a drive mechanism which has a pulley 31 and a belt 32 over the pulley 31. Moreover, not shown in the drawing, it is fine that the drive mechanism is configured of a wire, a gear and the like instead of the belt. Besides, it is acceptable that the holder member 21 is configured to have a so-called clamping mechanism in the holding part 24, the clamping mechanism clamps the sample 3 placed on the mounting recess 27.

The processing beam part 12 is a focused ion beam irradiation apparatus, for example, its lens-barrel is disposed vertically above the vacuum container 10, having a gallium liquid metal ion source which is a processing beam source (not shown in the drawing) and an ion optical system which focuses, scans and irradiates ion beams from the gallium liquid metal ion source. The processing beam part is disposed so that the irradiation axis (the center axis of the lens-barrel) of the focused ion beam is vertical with respect to the sample 3.

The removing beam part 13 is a gaseous ion beam irradiation apparatus, for example, and is disposed at the position to approach the cross section 4 of the sample 3, having a the removing beam source (gaseous ion gun) (not shown in the drawing) which irradiates an inert ion beam such as argon gas and helium gas

of inert gas. The removing beam part 13 is disposed so that its irradiation axis (the center axis of the lens-barrel) toward the cross section 4 of the sample 3 is tilted at an angle of about 35 degrees in the upper slanting direction with respect to the horizontal direction. Furthermore, it is acceptable that the removing beam source is configured to irradiate an oxygen ion beam with oxygen as necessary. It is fine that a chemical species at this time is oxygen radicals other than oxygen ions.

The observing beam part 14 is an electron beam irradiation apparatus, for example, and is disposed at the position to approach the cross section 4 of the sample 3, having an electron gun (not shown in the drawing) which irradiates an electron beam, and a TEM detector 33 which detects transmission electrons having been irradiated from the electron gun and transmitted through the cross section 4 of the sample 3. The observing beam part 14 is disposed so that its irradiation axis (the center axis of the lens-barrel) is tilted at an angle of about 35 degrees in the upper slanting direction with respect to the horizontal direction. As shown in Figs. 1 and 7(c), the detector 33 is disposed at the position to face the electron gun as sandwiching the cross section 4 of the sample 3. In addition, the observing beam part 14 described above takes the transmission mode, but it is acceptable to configure to have the reflection mode in which the detector is disposed at the position to approach the

top surface side of the sample 3, for example, and detects secondary electrons reflected in the cross section 4.

A method in which the ion beam apparatus 1 thus configured is used to process the observation cross section 4 in the sample 3 and to observe the cross section 4 will be describe with reference to the drawings.

First, when the ion beam apparatus 1 processes the cross section 4 in the sample 3 as shown in Fig. 7(a), the irradiating direction of the focused ion beam is approximately orthogonal to the top surface of the sample 3 at the initial position where the sample is held by the holding part 24 of the holder member 21. At the initial position, a processing beam source irradiates the focused ion beam onto the sample 3 to form the cross section 4.

Here, problems traditionally generated in irradiating the focused ion beam onto the sample to process the cross section will be described briefly.

As schematically shown in Fig. 12(a), when a recess 111 is on a top surface (front surface) 109 of a sample 108 to approach the processing beam source side, variations occur in the processing rate depending on the shape of the top surface 109 of the sample 108. Therefore, as shown in Fig. 12(b), a problem arises that streaks 112 in bumps and dips are generated on a cross section 110 along the irradiating direction of the focused ion beam on the borders of the recess 111. Furthermore, these

streaks 112 are also generated when the border between different materials exist on the top surface 109 of the sample 108. Similarly, a problem also arises that an argon ion beam is irradiated onto the cross section 110 of the sample 108 to generate streaks when a fracture layer is removed from the cross section 110.

Then, these streaks 112 are generated on the cross section 110 of the sample 108 to cause harm to obtaining an excellent observed image of the cross section 110 in observation by the observing beam part.

For measures against these problems, in the embodiment, as shown in Fig. 8, when the cross section 4 is processed in the sample 3 by the focused ion beam, the holding part 24 is rotated in the directions of b_1 , b_2 . Thus, the cross section 4 is rotated at the position where it is tilted only at a desired angle with respect to the irradiating direction of the focused ion beam, and then processing by the focused ion beam is repeated at least more than once. Accordingly, streaks generated by fine bumps and dips and the border between different materials on the top surface of the sample 3 are removed from the cross section 4 of the sample 3 and gradually reduced as processing is repeated, and then a smooth cross section 4 with inconspicuous streaks is formed.

Subsequently, as shown in Fig. 7(b), the ion beam apparatus 1 rotates the holder member 21 at an angle of about 145 degrees,

for example, in the direction of a_1 from the initial position, and adjusts the irradiating direction of an inert ion beam by the removing beam part 13, the beam is irradiated onto the cross section 4 of the sample 3 held by the holding part 24.

More specifically, as shown in Fig. 9, to the sample 3 held by the holder member 21, the removing beam source is positioned on the holding end side of the sample 3 with respect to the normal L perpendicular to the cross section 4 when the inert ion beam is irradiated onto the cross section 4, and the irradiating direction of the inert ion beam to be irradiated onto the cross section 4 is tilted at the tilt angle θ with respect to the normal L . The tilt angle θ ranges in $90^\circ > \theta > 0^\circ$, and a large angle θ is fine as much as possible depending on the shape of the sample 3 and the size and the like of the holding part 24. In the embodiment, it is set from about 70 to 80 degrees, for example.

Then, for the sample 3, the irradiating direction of the inert ion beam for the cross section 4 is tilted at the tilt angle θ with respect to the normal L . Thus, the inert ion beam is irradiated onto the side surface of the step part adjacent to the cross section 4 and secondary particles of the fracture layer are flown. However, the flown secondary particles travel in the direction where they do not reach the cross section 4. Therefore, it is reduced that the secondary particles removed from the fracture layer of the cross section 4 are again attached

onto the cross section 4 to contaminate the cross section 4.

Similarly, as shown in Fig. 8, when the fracture layer is removed from the cross section 4 of the sample 3 by the inert ion beam, the holding part 24 is also rotated in the directions of b_1 , b_2 . Thus, the cross section 4 is rotated at the position where it is tilted only at a desired angle with respect to the irradiating direction of the inert ion beam, and processing by the inert ion beam is repeated at least more than once. Accordingly, streaks generated by fine bumps and dips and the border between different materials on the top surface of the sample 3 are removed from the cross section 4 of the sample 3 and gradually reduced as processing is repeated, and then a smooth cross section 4 with inconspicuous streaks is formed.

Furthermore, to the sample 3, the inert ion beam is irradiated onto the other cross section 4 at the position at an angle of about 40 degrees rotated in the direction of a_2 from the position where the inert ion beam has been irradiated onto one of the cross sections 4, and then the fracture layer is removed.

Moreover, it is acceptable that when the cross section 4 is processed by the focused ion beam and the fracture layer is removed by the inert ion beam in order to remove above-described streaks generated on the cross section 4 of the sample 3, the focused ion beam or inert ion beam is irradiated onto the sample 3 while the holding part 24 is being rotated

in the directions of b_1 , b_2 , and thus processing is done as the irradiating direction of the focused ion beam or inert ion beam is varied to the sample 3.

Besides, in the embodiment, the holding part 24 is rotated when the cross section 4 is processed by the focused ion beam and the fracture layer is removed by the inert ion beam in order to remove streaks. However, it is acceptable that streaks are collectively removed when the fracture layer is removed by the inert ion beam. In addition, when streaks are collectively removed by the inert ion beam, the irradiating direction of the inert ion beam with respect to the cross section 4 needs to be varied from the irradiating direction of the focused ion beam with respect to the sample 3.

Lastly, as shown in Fig. 7(c), the ion beam apparatus 1 rotates the holder member 21 at an angle of 180 degrees in the direction of a_2 , for example, from the rotational position where the inert ion beam has been irradiated, that is, the apparatus rotates it at an angle of 35 degrees in the direction of a_2 with respect to the initial position. Therefore, the irradiating direction of the electron beam by the observing beam part 14 is adjusted, the beam is irradiated onto the cross section 4 of the sample 3 held by the holding part 24. At the rotational position, the observing beam part 14 irradiates the electron beam onto the cross section 4 of the sample 3, the detector 33 detects transmission electrons having been

transmitted through the cross section 4, and thus an excellent observed image of the cross section 4 can be obtained.

As described above, the ion beam apparatus 1 rotates the holder member 21 in the directions of a_1 , a_2 , it tilts the irradiating direction of the inert ion beam with respect to the cross section 4 of the sample 3 only at the tilt angle θ to the normal L of the cross section 4, and then the fracture layer is removed. Thus, it can be reduced that the secondary particles of the removed fracture layer are again attached onto the cross section. On this account, according to the ion beam apparatus 1, the smooth cross section 4 with the fracture layer excellently removed can be obtained, and the cross section 4 can be observed by the observing beam part 14 excellently.

Furthermore, the holder part 11 provided to the ion beam apparatus 1 has the holder member 21 having the holding part 24 rotatably disposed in the directions of b_1 , b_2 , and thus streaks generated in the cross section 4 of the sample 3 that is processed by the focused ion beam can be small to improve smoothness of the cross section 4.

Lastly, in the ion beam apparatus 1 described above, the removing beam part 13 is disposed in the upper slanting direction with respect to the sample 3 on the holder member 21. Another ion beam apparatus in which the removing beam part 13 is disposed at the different position will be described briefly. In addition, as compared with the ion beam apparatus 1 described

above, since another ion beam apparatus is varied at the positions of the removing beam part 13 and the observing beam part 14, the same numeral and signs are designated the same components, omitting the description.

As shown in Fig. 10, in another ion beam apparatus 2, a removing beam part 13 is disposed so as to irradiate an inert ion beam onto a sample 3 on a holder member 21 from the lower slanting direction, and an observing beam part 14 is disposed so as to irradiate an electron beam onto the sample 3 on the holder member 21 from the horizontal direction.

According to the ion beam apparatus 2 thus configured, the holder member 21 does not need to be rotated in the directions of a_1 , a_2 , and therefore the configuration of the holder member 21 can be simplified. Furthermore, it is acceptable that in the ion beam apparatus, the relative position of the removing beam part 14 with respect to a cross section 4 of the sample 3 can be set depending on the rotational range of the holder member 21 in the directions of a_1 , a_2 .

Therefore, it is acceptable that the ion beam apparatus according to the invention is configured in which the holder part 11, the removing beam part 13 and the observing beam part 14 are disposed at given positions when it is configured in which the inert ion beam is irradiated from the holding end side of the sample 3 with respect to the normal L of the cross section 4 of the sample 3 so that its irradiating direction

is tilted with respect to the normal L.

In addition, the embodiment is configured as the side entry ion beam apparatus 1 having the processing beam part 12, but it is not limited to this configuration. For example, it can be configured to have the holder part 11 and the removing beam part 13 without the processing beam part 12, and to have the observing beam part 14 in addition to this configuration.

Industrial Applicability

As described above, according to the ion beam apparatus of the invention, it is provided with the removing beam source which irradiates the gaseous ion beam from the holding end side of the sample with respect to the direction vertical to the processed surface of the sample so that its irradiating direction is tilted with respect to the vertical direction. Thus, it is reduced that the fracture layer removed by the gaseous ion beam is again attached onto the processed surface. Accordingly, the ion beam apparatus according to the invention can excellently remove the fracture layer from the processed surface, and a smooth processed surface can be obtained.

Furthermore, in the ion beam apparatus according to the invention, the holder member has the base part which is rotatably supported about the first axis in parallel with the horizontal direction, and the holding part which is rotatably disposed about the second axis orthogonal to the first axis

at the tip end side of the base part and holds the sample. Thus, the arrangement of the removing beam source with respect to the holder member and the flexibility in the irradiating direction of the gaseous ion beam are secured, and the irradiating direction of the ion beam can be varied with respect to the processed surface of the sample held by the holding part.

Moreover, according to the ion beam processing method of the invention, the gaseous ion beam is irradiated from the holding end side of the sample with respect to the direction vertical to the processed surface of the sample at the second step so that its irradiating direction is tilted with respect to the vertical direction. Thus, it can be reduced that the fracture layer removed by the gaseous ion beam is again attached onto the processed surface, and the fracture layer can be excellently removed from the processed surface to obtain a smooth processed surface.

Besides, according to the holder member of the invention, it has the base part which is rotatably supported about the first axis in parallel with the horizontal direction, and the holding part which is rotatably disposed about the second axis orthogonal to the first axis at the tip end side of the base part and holds the sample where the focused ion beam is irradiated to form the processed surface. Therefore, the irradiating directions of the focused ion beam and the gaseous ion beam can be varied with respect to the processed surface of the sample.

Accordingly, according to the holder member of the invention, the irradiating direction of the focused ion beam or the gaseous ion beam can be varied for processing to reduce streaks to be generated in the processed surface. Thus, smoothness of the processed surface can be improved.